

Claims

1. A cannula for use in the transfer of small volumes of fluid materials such as in a parallel reaction process, said cannula comprising

- 5 a reservoir having an inside dimension defining an interior for containing said fluid materials, an outside dimension, a proximal end and a distal end, said reservoir having a capacity in a range of 10-5000 microliters,
- 10 a long thin needle having an outside dimension substantially less than the outside dimension of the reservoir and an inside surface defining a flow passage through the needle, said needle further having a proximal end, a distal end, and a port adjacent said distal end for the transfer of said fluid materials to and from the needle,
- 15 a transition joining the proximal end of the needle to the distal end of said reservoir so that the interior of the reservoir is in fluid communication with the flow passage of the needle.

20 2. A cannula as set forth in claim 1 wherein the needle is of metal.

3. A cannula as set forth in claim 2 wherein the reservoir and transition are of metal, and wherein the reservoir, needle and transition are welded together.

4. A cannula as set forth in claim 1 wherein the reservoir, needle and transition have interior surfaces which are joined together to form a continuous smooth interior expanse extending from the reservoir to the transition to the  
5 needle.

5. A cannula as set forth in claim 4 wherein said reservoir comprises a cylindric body, and wherein said transition is generally funnel-shaped to have an sloping side

wall, a bottom wall, and a hole through the bottom wall  
5 receiving a distal end portion of the needle, the distal end  
of the needle being flush with the interior surface of the  
transition.

6. A cannula as set forth in claim 5 wherein said  
transition is joined to the reservoir and needle by welds,  
and wherein the welds are polished to a smooth finish on the  
inside of the cannula.

7. A cannula as set forth in claim 1 wherein the port  
of the needle faces laterally away from a longitudinal axis  
of the needle.

8. A cannula as set forth in claim 7 wherein said port  
is directed at an oblique angle relative to said longitudinal  
axis.

9. A cannula as set forth in claim 8 wherein said  
oblique angle is in the range of 15-45 degrees.

10. A cannula as set forth in claim 8 wherein said  
oblique angle is in the range of 20-30 degrees.

11. A cannula as set forth in claim 7 wherein the port  
of the needle is elongate in shape and has a minimum  
dimension in the range of 0.005-0.12 in.

12. A cannula as set forth in claim 7 wherein the port  
of the needle has a minimum dimension about the same as the  
inside diameter of the needle.

13. A cannula as set forth in claim 7 wherein the  
distal end of the needle has a rounded exterior end surface.

14. A cannula as set forth in claim 13 wherein said port is spaced away from said rounded exterior end surface.

15. A cannula as set forth in claim 13 wherein said port is in said rounded exterior end surface.

16. A cannula as set forth in claim 13 wherein said rounded exterior end surface is generally hemispherical in shape.

17. A cannula as set forth in claim 14 wherein said needle comprises a tubular shaft defining a flow passage and an end piece welded to the tubular shaft.

18. A cannula as set forth in claim 17 wherein said port is constituted by a bore drilled to intersect said flow passage at an elbow.

19. A cannula as set forth in claim 1 wherein said needle comprises a tubular shaft defining a flow passage and an end piece welded to the tubular shaft, said end piece having a smooth rounded exterior end surface constituting a tip of the needle, and wherein said port is in said tubular shaft.

20. A cannula as set forth in claim 1 wherein said needle has a length of about 2.0-4.0 in.

21. A cannula for use in the transfer of fluid materials such as in a parallel reaction process, said cannula comprising

a long thin needle having an inside surface defining a flow passage through the needle, a proximal end, a distal end, and a port adjacent said distal end directed at an oblique angle relative to a longitudinal axis of the needle for the transfer of said fluid materials to and from the

needle, and

an adapter for connecting the needle to a fluid line, said adapter having a distal end connected to the proximal end of the needle, a proximal end for connection to the fluid line, and an interior for directing the transfer of fluid between the fluid line and the flow passage of the needle.

22. A cannula as set forth in claim 21 wherein said oblique angle is in the range of 15-45 degrees.

23. A cannula as set forth in claim 21 wherein said oblique angle is in the range of 20-30 degrees.

24. A cannula as set forth in claim 21 wherein the port of the needle is elongate in shape and has a minimum dimension in the range of 0.005-0.12 in.

25. A cannula as set forth in claim 21 wherein the port of the needle has a minimum dimension about the same as the inside dimension of the needle.

26. A cannula as set forth in claim 21 wherein said adapter comprises a reservoir having a proximal end for connection to said fluid line and a distal end, and a transition connecting the distal end of the reservoir and the proximal end of the needle, said transition being shaped to funnel fluid from the reservoir to the needle.

27. A cannula as set forth in claim 21 wherein said adapter comprises a transition having a proximal end for connection to said fluid line and a distal end connected to said needle.

28. A cannula as set forth in claim 27 wherein said transition has a flow passage therethrough tapered toward the distal end of the transition.

29. A cannula as set forth in claim 27 further comprising a fitting formed as an integral part of the transition for connection of the fluid line to the transition.

30. A cannula for use in the transfer of fluid materials such as in a parallel reaction process, said cannula comprising

a long thin needle having a longitudinal axis, an inside surface defining a flow passage through the needle, a proximal end, a distal end, and a port spaced from said distal end and directed laterally away from said a longitudinal axis for the transfer of said fluid materials to and from the needle, and

an adapter for connecting the needle to a fluid line, said adapter having a distal end connected to the proximal end of the needle, a proximal end for connection to the fluid line, and an interior for directing the transfer of fluid between the fluid line and the flow passage of the needle,

said distal end of the needle having a smooth, rounded exterior end surface substantially free of exposed sharp edges.

31. A cannula as set forth in claim 30 wherein the needle comprises a tubular shaft and an end piece attached to the shaft, and wherein said port is in the shaft spaced from said rounded exterior end surface.

32. A cannula as set forth in claim 30 wherein said port is in said rounded distal end surface.

33. A cannula as set forth in claim 30 wherein said distal end surface is hemispherical.

34. A cannula as set forth in claim 30 wherein said adapter comprises a reservoir having a proximal end for connection to said fluid line and a distal end, and a transition connecting the distal end of the reservoir and the proximal end of the needle, said transition being shaped to funnel fluid from the reservoir to the needle.

35. A cannula as set forth in claim 30 wherein said adapter comprises a transition having a proximal end for connection to said fluid line and a distal end connected to said needle.

36. A cannula as set forth in claim 35 wherein said transition has a flow passage therethrough tapered toward the distal end of the transition.

37. A cannula as set forth in claim 35 further comprising a fitting formed as an integral part of the transition for connection of the fluid line to the transition.

38. A cannula for use in the transfer of fluid materials such as in a parallel reaction process, said cannula comprising

a long thin needle having a longitudinal axis, an inside surface defining a flow passage through the needle, a proximal end, a distal end, and a port spaced from said distal end and directed laterally away from said longitudinal axis for the transfer of said fluid materials to and from the needle, and

an adapter comprising a transition for connecting the needle to a fluid line, said transition having a distal end connected to the proximal end of the needle, a proximal end

adapted for connection to the fluid line, and a flow passage in the transition tapered toward the distal end of the transition.

39. A cannula as set forth in claim 38 wherein the proximal end of the needle is secured in a recess in the distal end of the transition.

40. A cannula as set forth in claim 39 wherein the transition and the needle are of metal, and the needle is secured in said recess by welding.

41. A cannula as set forth in claim 38 wherein said port opens laterally away from a longitudinal axis of the needle.

42. A cannula as set forth in claim 38 further comprising a fitting at the proximal end of the transition for attachment of said fluid line to the transition.

43. A cannula as set forth in claim 42 wherein said fitting is formed an integral part of the transition.

44. A cannula as set forth in claim 38 wherein the needle has an inside dimension at its proximal end substantially identical to the dimension of the transition flow passage at its distal end.

45. A robotic fluid transfer system, comprising  
  
a cannula sized for holding 10 $\mu$ l-5000 $\mu$ l of a fluid material,  
and

a robot system for transporting the cannula to a fluid transfer location, said robot system being operable to move the cannula along a first x axis, a second y axis, and a

third z axis, and also for rotating the cannula to vary the angular orientation of the cannula.

46. A robotic fluid transfer system as forth in claim 45 wherein said cannula is rotatable to an angled position for the transfer of fluid at said fluid transfer location, and wherein said robot system is operable for moving said cannula along a longitudinal axis of the cannula when said cannula is in said angled position at said fluid transfer location.

47. A robotic fluid transfer system as set forth in claim 45 wherein said cannula is rotatable about an r axis parallel to said y axis.

48. A robotic fluid transfer system as set forth in claim 45 wherein said robot system comprises a robot arm rotatable about an r axis extending generally parallel to said arm, a mount on the arm for mounting the cannula, and a rotating mechanism for rotating the arm about said r axis.

49. A robotic fluid transfer system as set forth in claim 48 wherein said rotating mechanism comprises an actuator for rotating said arm in two directions, a first stop for limiting rotation of the arm in one direction to stop the arm at a position corresponding to an angled position of the cannula, and a second stop for limiting rotation of the arm in an opposite direction to stop the arm at a position corresponding to a different position of the cannula.

50. A robotic fluid transfer system as set forth in claim 49 wherein said actuator comprises a double-acting power cylinder.



51. A robotic fluid transfer system as set forth in claim 48 wherein said cannula comprises a needle with a flow passage therein, and wherein said apparatus further comprises a cannula support on the mount engageable with the needle intermediate opposite ends of the needle for supporting and stabilizing the needle in precise position as the cannula is moved.

52. A robotic fluid transfer system as set forth in claim 51 wherein said cannula support comprises a body affixed to the cannula mount and a head mounted on the body and having an opening therein sized for a close clearance fit with said needle, said head being movable relative to the body from an extended position in which the head is spaced from the body for engagement with a more distal portion of the needle, and a retracted position in which the head is closer to the body for engagement with a more proximal portion of the needle to allow for insertion of the said more distal portion of the needle into a cannula passage.

53. A robotic fluid transfer system as set forth in claim 45 further comprising a fluid transfer system for effecting the transfer of fluid from the cannula at said fluid transfer location.

54. A robotic fluid transfer system as set forth in claim 45 further comprising a cannula passage at said fluid transfer location for receiving said cannula to effect the transfer of fluid, and a sealing mechanism in said cannula passage for sealing against leakage of fluid from the passage during said transfer.

55. A robotic fluid transfer system as set forth in claim 54 wherein said cannula comprises a needle and an adapter for connecting the needle to a fluid flow line, said needle being adapted to be inserted in said cannula passage

and said sealing mechanism being adapted to seal around the needle when the needle is in the passage.

56. A robotic fluid transfer system as set forth in claim 54 wherein said sealing mechanism comprises a valve movable between a closed position for closing the cannula passage and an open position permitting movement of the cannula through the passage, and a seal in the passage adapted for sealing with the cannula when the valve is in its open position.

57. A robotic fluid transfer system as set forth in claim 54 wherein said cannula passage is in fluid communication with a reaction vessel contained in a reactor.

58. A robotic fluid transfer system as set forth in claim 57 wherein said fluid passage is in isolatable fluid communication with said reaction vessel.

59. A robotic fluid transfer system, comprising

a cannula adapted for containing fluid,

a robot system for transporting the cannula to a fluid transfer location, said robot system being operable to move the cannula along a first axis x, a second axis y, and a third axis z, and also for rotating the cannula to vary the angular orientation of the cannula,

a cannula passage at said fluid transfer location for receiving said cannula to effect the transfer of fluid,

a fluid transfer system for effecting fluid transfer while said cannula is in said cannula passage, and

a sealing mechanism in said cannula passage for sealing

against leakage of fluid from the passage during said fluid transfer.

60. A robotic fluid transfer system as set forth in claim 59 wherein said cannula passage is angled off vertical.

61. A robotic fluid transfer system as set forth in claim 59 wherein said sealing mechanism comprises a valve movable between a closed position for closing the cannula passage and an open position permitting movement of the cannula through the passage, and a seal in the passage adapted for sealing contact with the cannula when the valve is in its open position.

62. A robotic fluid transfer system as set forth in claim 59 wherein said cannula comprises a needle and an adapter for connecting the needle to a fluid flow line, said needle being adapted to be inserted in said cannula passage and said sealing mechanism being adapted to seal around the needle when the needle is in the passage.

63. A robotic fluid transfer system as set forth in claim 59 wherein said cannula passage is in fluid communication with a reaction vessel contained in a reactor.

64. A robotic fluid transfer system as set forth in claim 63 wherein said fluid passage is in isolatable fluid communication with said reaction vessel.

65. A method of transferring fluids using a cannula, comprising

connecting the cannula to a robot transport system,

operating the robot transport system to transport the cannula to a fluid transfer location, said transport involving moving

said cannula along x, y and z axes, rotating the cannula to an angular orientation off vertical, and inserting the cannula while in said angled orientation into an angled cannula passage, and

effecting transfer of said fluid while said cannula is in said angled cannula passage.

66. A method as set forth in claim 65 wherein the cannula is sized for holding 10 $\mu$ l-5000 $\mu$ l of fluid.

67. A method as set forth in claim 65 further comprising advancing the cannula through a sealing mechanism in said cannula passage before effecting transfer of said fluid to prevent the leakage of fluid from the passage.

68. A method as set forth in claim 65 wherein said fluid transfer is effected at a pressure other than ambient pressure.

69. A method as set forth in claim 65 wherein said fluid transfer is effected at a pressure of at least about 15 psig.

70. A method as set forth in claim 65 wherein said fluid transfer is effected at a pressure of about 50-500 psig.

71. A method as set forth in claim 65 wherein said cannula passage is in fluid communication with a reaction vessel contained in a reactor.

72. A method as set forth in claim 65 further comprising aspirating a sample of fluid material into said cannula at said fluid transfer location, operating said robot transfer system to transport said cannula to a sample

analyzing device, and effecting transfer of fluid from the cannula to said sample analyzing device.

73. A method as set forth in claim 72 further comprising aspirating said fluid sample from a reactor vessel containing fluid reaction materials.

74. A method as set forth in claim 65 wherein the amount of fluid transferred is from about 5 $\mu$ l-500 ml.

75. A method as set forth in claim 65 wherein the amount of fluid transferred is from about 1 ml-500 ml.

76. A method as set forth in claim 65 wherein the amount of fluid transferred is from about 2 ml-25 ml.